Coordination Between Airway Facilities and Air Traffic: Empirical Findings

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Introduction

When two or more organizations work together to accomplish a task, they need to coordinate. Coordination becomes more difficult as tasks get more complex and organizations become more diverse. One good example is the coordination involved in building the Boeing 767-F (Klein, 2000). To build it, many people in different disciplines needed to work together to put millions of parts in place.

Researchers have identified several factors involved in successful coordination. Sharing information is the most critical factor (Klein, 2000; MacDonald, 1998; Smith et al., 1998). Another important factor is a person's mental model knowing the other's tasks and responsibilities (Converse, Cannon-Bowers, & Salas, 1991; Langan-Fox, Code, & Langfield-Smith, 2000; Smith et al.). Participants need to have trust and clearly understand their roles and responsibilities (Malone & Crowston, 1994: Smith et al.). Communication and methods in communication are other important factors (Smith et al.; Warkentin, Sayeed, & Hightower, 1997). It is also important to relay necessary information on time and receive feedback in a timely manner (Smith et al., 1998).

In 1997, the Federal Aviation Administration (FAA) presented new operational concepts of air traffic service to be realized in 2005 (FAA, 1997a). One of the major characteristics in this new National Air Space (NAS) was increased coordination between the NAS providers and users. Although the NAS providers and users have coordinated well in the past, they realized that new ways of coordination would facilitate coordination between them and make the NAS safer and more efficient. The FAA extended this philosophy to the NAS infrastructure maintenance to "facilitate collaboration between service providers and users, allowing users to participate in prioritizing scheduled and unscheduled repairs to essential NAS equipment" (FAA, 1999a, p. 4).

In the FAA, there are two organizations: Airway Facilities (AF) and Air Traffic (AT). AT is responsible for controlling safe and efficient air traffic, and AF is responsible for providing services and maintenance that deliver the highest possible levels of National Airspace System (NAS) safety and efficiency (Federal Aviation Administration [FAA], 1999b).

AF's tasks may be periodic maintenance to "minimize unscheduled interruptions as well as extend life of the equipment and infrastructure" or corrective maintenance to restore the NAS service "after an outage or unscheduled interruption" (FAA, 1999c, p. 2). This corrective maintenance also includes "fault detection, troubleshooting, fault isolation, and replacement of any failed components" (FAA, 1999b, p. 2). To perform these tasks, AF specialists usually need to coordinate with personnel at various organizations, including Air Traffic (AT). Even though the coordination between AF and AT involves only two organizations, the implication of failed coordination to the NAS safety is enormous. Therefore, the efficient and seamless coordination between these two organizations is very critical for the NAS.

The objective of this research was to study coordination between AF and AT in current scheduling maintenance activities. We designed questionnaires to explore it if the major factors in efficient coordination were realized in the current AF and AT coordination. Based on the data we collected, we present recommendations to make the current coordination between AF and AT more efficient. Our questionnaires were specifically designed to examine coordination between AF and AT, but this questionnaire design can be used to examine coordination between any organizations.

Method

In AF, Maintenance Control Center (MCC) specialists were the focal point of coordination. There were 42 regional Maintenance Control Centers (MCCs) (FAA [MCC Information], 2000). As of

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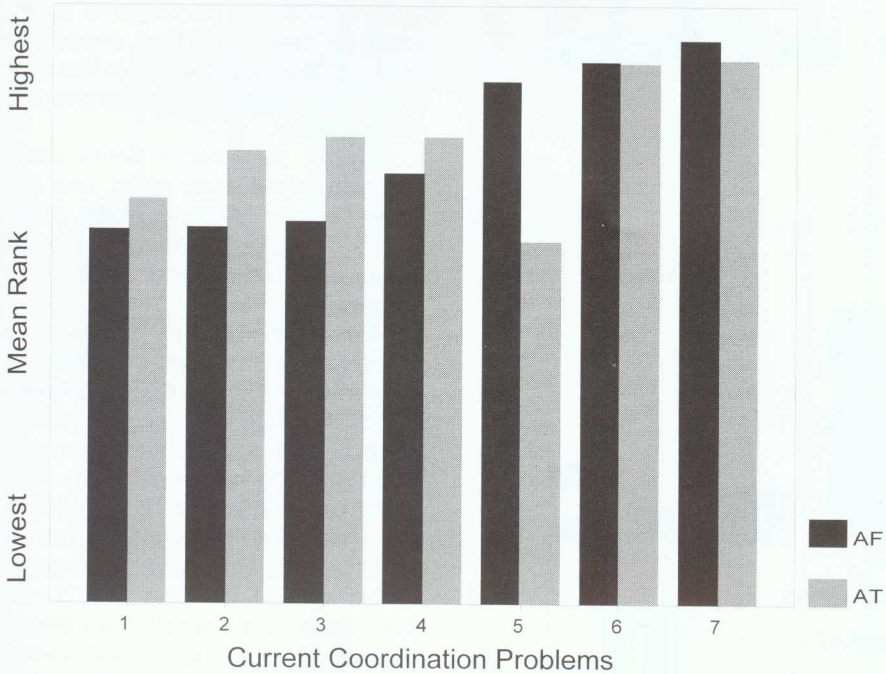

1. Communication method
2. Unclear roles
3. Unclear with whom to coordinate and when
4. Inability to reach the right person
5. Too many groups to coordinate with
6. Not getting information that you need in sufficient time
7. Insufficient or inaccurate information

Figure 1. Current problems in coordination perceived by AF and AT respondents (Note: "Other" and "None" were given as possible choices, but not many people chose them. We omitted them for simplicity in the graphic presentation.)

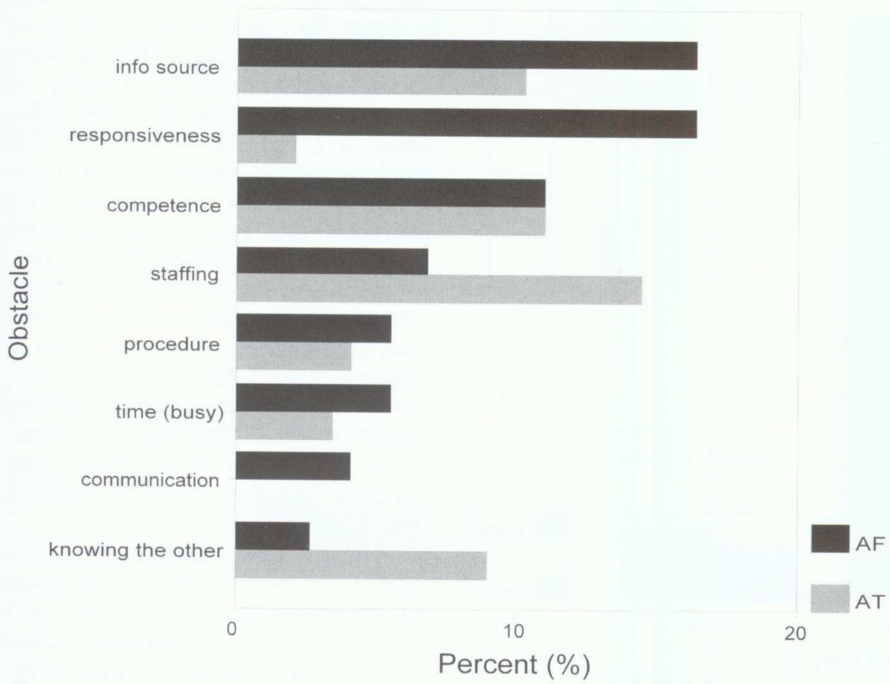

Figure 2. Obstacles to efficient coordination as perceived by AF and AT respondents.

October 26, 2000, 488 MCC AF specialists worked in these centers. There were two kinds of MCCs: the Air Route Traffic Control Center (ARTCC) MCC (AMCC) and the General MCC (GMCC). AMCCs were collocated at ARTCCs. AMCCs' task was to maintain equipment and systems that served the ARTCC directly and exclusively. GMCCs were responsible for all coordination activities for facilities that supported the terminal environment and en route navigational aids (FAA, 1999a; FAA, 1999b). (Note: Since we collected the data for this study, the AF structure has changed. The FAA has been in the process of dissolving GMCCs into one of Atlantic, Mid-States, or Pacific Operations Control Centers. AMCCs became Service Operations Centers.)

We sent out 282 questionnaires to 21 randomly chosen MCCs (12 AMCCs and 12 9 GMCCs). We analyzed 95 AF questionnaires. Among the respondents, 57 belonged to AMCCs, 31 to GMCCs, and 7 were unknown.

In AT, supervisors are responsible for coordination. To understand the perspectives on coordination from the AT side, we sent out 370 similar questionnaires to AT supervisors of ARTCCs, Terminal Radar Approach Controls (TRACONs), and Air Traffic Control Towers (ATCTs). We selected AT facilities independently from the AF facilities where we sent AF questionnaires. We analyzed 179 AT questionnaires.

Results

Our questionnaires touched all of the major factors in efficient coordination, and respondents' data are presented in the following sections representing those major factors. (Note: In the following, the percentages are based on the number of respondents who answered the particular question, not the total number of AF or AT respondents.)

Information

The data from the questionnaire showed that there were informa-

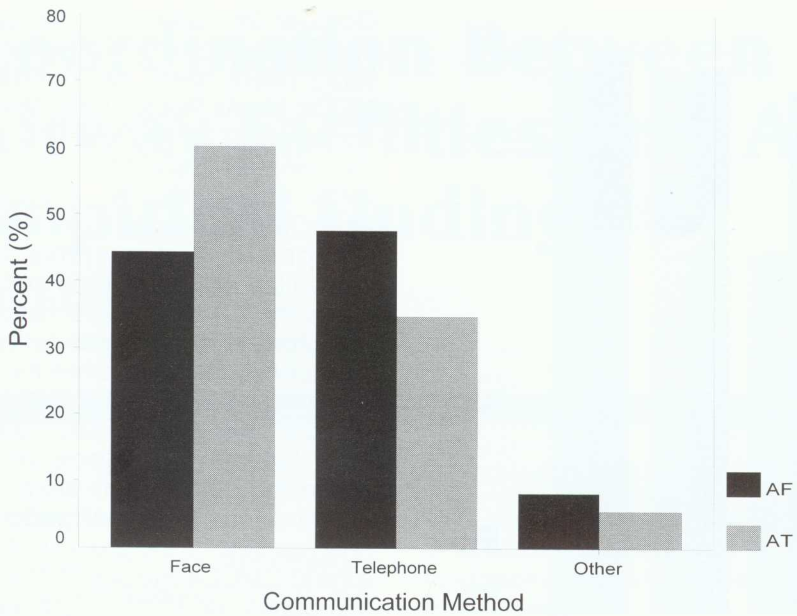

Figure 3. Communication methods of AF and AT.

tion-related problems between AF and AT. AF and AT respondents ranked "insufficient or inaccurate information" and "not getting information that you need in sufficient time" as the highest ranked problems (Figure 1). Also, for the open-ended question on obstacles, 20 (27) AF respondents and 44 (30%) AT respondents cited information-related problems most often (that is, e.g., information source, staffing, quality, sharing and exchanging, and terminology) (Figure 2).

Communication Method

According to previous research, face-to-face communication was the most effective communication method in coordination (Smith et al., 1998; Warkentin et al., 1997). Warkentin et al. (1997) showed that if coordination was done electronically or virtually, participants experienced team-building problems and got less satisfaction in the process than when they coordinated face-to-face.

Overall, AF respondents used the telephone most often and the face-to-face method quite often (Figure 3). AT respondents used the face-to-face method most often (Figure 3).

These frequencies seemed to depend on the work environment as shown in Figure 4. The respondents of AMCCs, which were collocated with ARTCCs, communicated face-to-face most often. This contrasted with the communication methods of respondents at GMCCs that were not always collocated with AT facilities. GMCC respondents used telephones extensively. AMCC respondents used face-to-face communication significantly more often than GMCC respondents ($p < .01$), and GMCC respondents used telephone communication significantly more often than AMCC respondents ($p < .01$) (Mann Whitney U test).

As summarized in Table 1, this collocation and face-to-face communication may have contributed to AMCC respondents' more positive ratings to coordination than GMCC respondents'. Mean differences between the two groups for all questions were statistically significant by *t* tests ($p < .05$) (Figure 4). On the AT side, ARTCCs were collocated with AF and some of non-ARTCCs (that is, TRACONs and ATCTs) were not. ARTCC respondents used face-to-face communication extensively, but non-ARTCC respondents used face-to-face and telephone communication about equally often (Figure 5). By using *t* tests and the same questions shown in Table 1, we tested if ARTCC and non-ARTCC respondents perceived the major coordination issues differently. We found no significant difference between them on any of the questions.

For our open-ended question about the most successful aspects of coordination, 18 AF (21%) and 24 AT (15%) respondents cited "face-to-face communication" (Figure 6). This was mentioned most

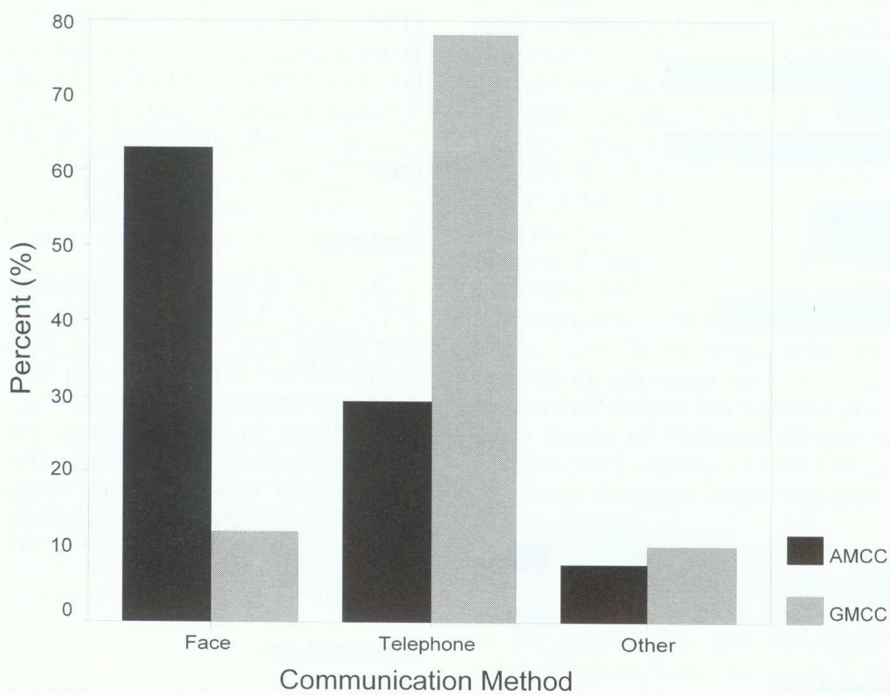

Figure 4. Communication methods of AMCC and GMCC.

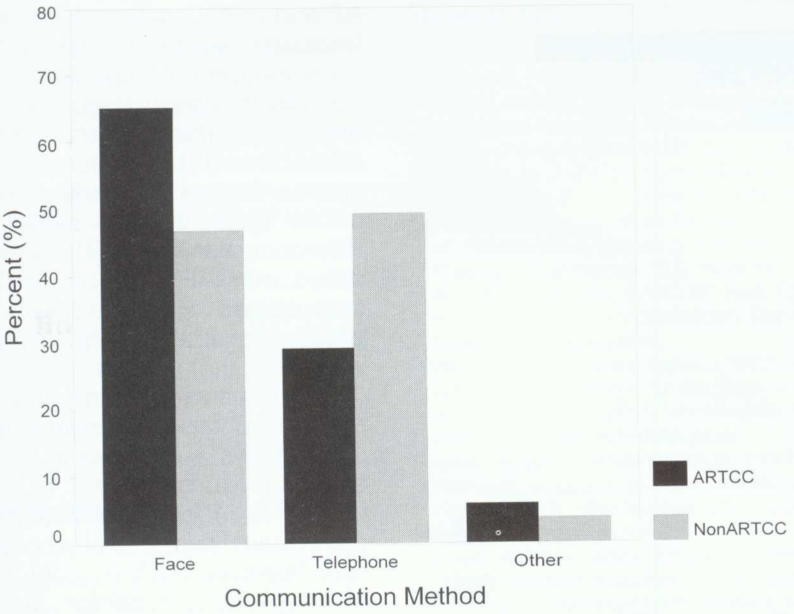

Figure 5. Communication methods by ARTCCs' and Non-ARTCCs' respondents.

often after "working relationship" by both AF and AT respondents.

Procedure and Control

We asked AF and AT personnel if there were clearly defined coordination roles and responsibilities. Their average ratings were 7.3 and 6.7, respectively (1= Strongly Disagree; 10 = Strongly Agree). To the open-ended question on improving current coordination, nine (9%) AF and six (3%) AT respondents suggested that the local control of coordination is important for efficient coordination (Figure 7).

Working Relationship

Thirty-one AF respondents (37%) and 40 AT respondents (25%) mentioned that a good working relationship inclusive of mutual trust and respect was the most successful aspect of the current coordination (Figure 6).

Distributing Responsibilities and Empowering

Researchers have claimed that to make coordination efficient, sometimes it is necessary to empower the other party and allow them to take initiatives (Eurocontrol, 1998; Lacher & Klein, 1993; MacDonald, 1998; Smith et. al, 1998). We asked AF personnel how often AT personnel prioritized AF's tasks. The mean rating was 3.4 (1 = Never; and 10 = Always). This means that AT respondents seldom prioritized AF tasks.

Mutual Understanding (or Mental Models)

Converse et al. (1991), Langan-Fox et al. (2000), and Smith et al. (1998) argued that a shared mental model helps coordination be effective. To test this, we asked AF personnel if they understood AT's tasks and responsibilities and how thoroughly AT personnel understood AF's roles and responsibilities. Their ratings were 7.6 and 6.0, respectively (1 = Barely; 10 = Extremely Well). We asked AT personnel the same question about AF. Their ratings were 6.6 and 6.4, respectively.

To the open-ended question, thirteen 13 (9%) AT respondents thought that AF's lack of understanding AT tasks was an obstacle to efficient coordination (Figure 2). Eleven (12%) AF and 6 (4%) AT respondents cited that understanding each other was one of the most important aspects in successful coordination (Figure 6).

Discussion

Respondents perceived information, responsiveness, local control, communication method, working relationship, and mutual understanding (or mental model) as the most influential factors in coordination. They cited working relationship as the most important factor. This relationship can be built upon mutual understanding or mental models of the other. Nonetheless, from AF respondents' rating of 7.6 (1 = Barely; 10 = Extremely Well) for the question of "How thoroughly do you understand AT tasks and

Table 1. Summary of AMCC and GMCC Respondents' Ratings on Major Coordination Factors

Questions	Average Rating AMCC	Average Rating GMCC
Current response times to maintenance requests are adequate. (Rating 1 for "Strongly Disagree" and Rating 10 for "Strongly Agree")	7.7	5.8
There are clearly defined roles for coordinating with AT. (Rating 1 for "Strongly Disagree" and Rating 10 for "Strongly Agree")	7.8	6.5
How thoroughly do you understand AT tasks and responsibilities? (Rating 1 for "Barely" and Rating 10 "Extremely Well")	8.2	6.6
How thoroughly do you think AT personnel understand your roles and responsibilities? (Rating 1 for "Barely" and Rating 10 "Extremely Well")	6.3	5.2
How successful is current AT/AF coordination? (Rating 1 for "Not Successful" and Rating 10 for "Extremely Successful")	8.5	7.3

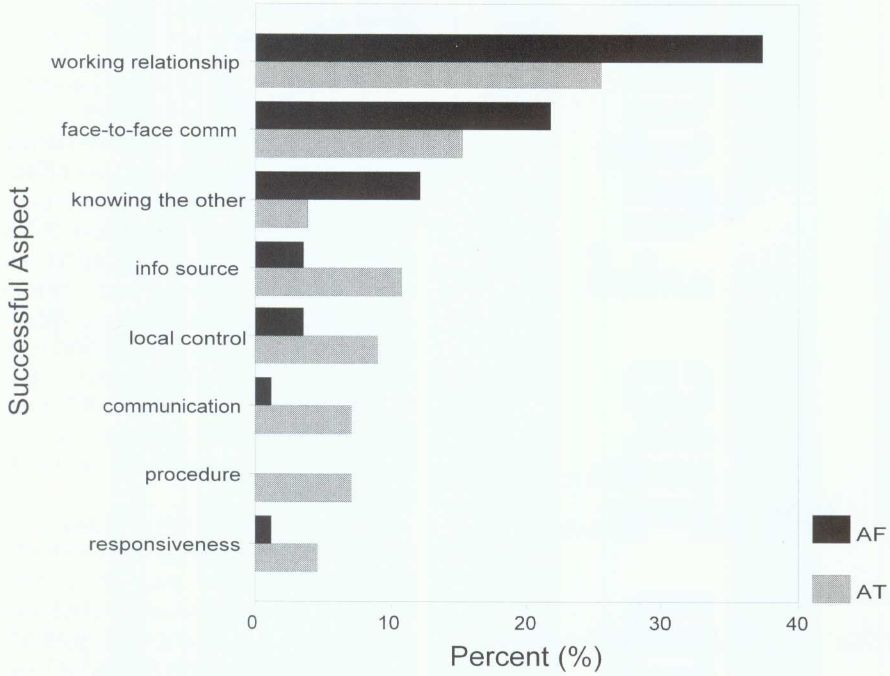

Figure 6. The most successful aspects in coordination as perceived by AF and AT respondents.

responsibilities?" and AT respondents' rating of 6.6 for the same question towards AF's tasks and responsibilities, we infer that respondents' mental models for the other were not well formed. Our data on the differences between AMCCs and GMCCs and also between ARTCCs and non-ARTCCs shed some light on this issue.

As presented in Table 1, AMCC respondents gave more positive ratings to coordination than GMCC respondents did. The major difference between AMCCs and GMCCs is AMCCs' collocation with AT and AMCC respondents' more frequent usage of face-to-face communication than GMCC respondents' usage (Figure 4). The effect of collocation may not be as influential as face-to-face communication in coordination because there was no significant difference between ARTCC (collocated with AF) and non-ARTCC (not always collocated with AF) groups on all of the questions in Table 1.

From the above results, we believe that face-to-face communication plays a vital role in coordination (Figures 4 and 5). This face-to-face communication implies many aspects of coordination, however. As they coordinate with each other in person, they receive instant feedback to their requests, build personal relationships, become familiar with the other's personality, and obtain information about the other's needs and requirements.

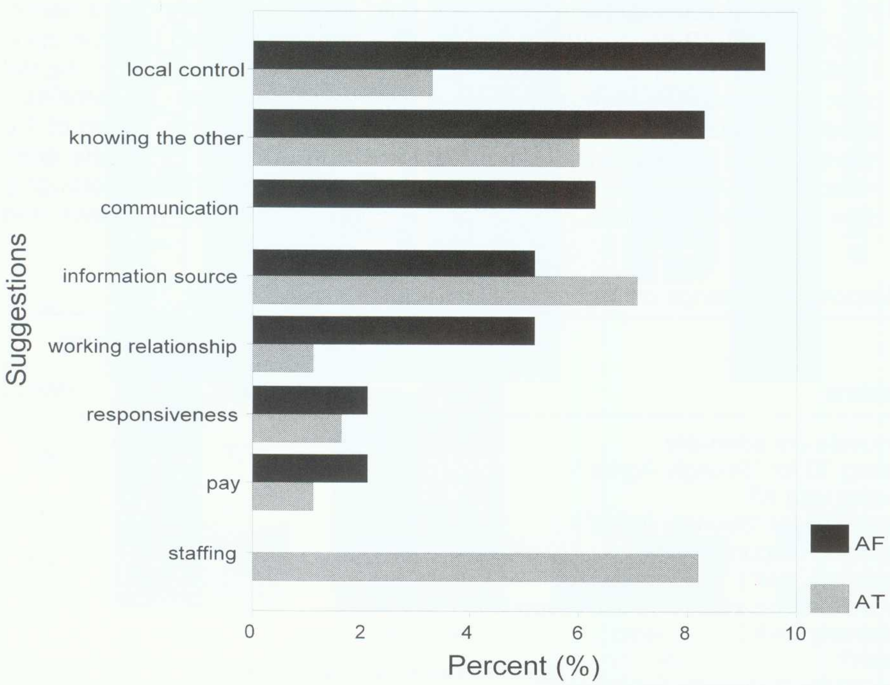

Figure 7. AF and AT respondents' suggestions to improve the current coordination.

Conclusion

We could examine all the major factors in coordination between two organizations (AF and AT) using survey questionnaires. Especially, they pointed out the importance of information, working relationships, responsiveness, and mutual understanding (or mental model) as critical factors for efficient coordination. We suggest that these critical factors could be facilitated by adopting local control, face-to-face communication, and joint meeting and training. The information-related obstacles such as finding the right coordinators and getting responses on time could be resolved by improving coordination procedures and training. Our survey methodology may be useful for any researchers who want to examine their own organizations' coordination.

Based on the data, we present the following recommendations to improve AT and AF coordination. These recommendations may be applicable to coordination between any other organizations.

- Facilitate mutual understanding.
- Devise measures to improve the information-related obstacles.

- Make the important, helpful information available to the coordinating personnel.
- Educate personnel who are not the main designated coordinators but may be called upon to coordinate. This could eliminate any confusion in coordinating.
- Create a separate, local coordination procedure. The current data and other previous studies suggest that local control and face-to-face communication are effective for coordination.
- Standardize the terminology.

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